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(54) Shut-off valve for limiting flow volume in an i.c. engine fuel injection system

(57) The shut-off valve 8 prevents fuel flowing uncontrollably into the engine cylinder if the injection nozzles are defective. The valve has an actuator 14 which is movable in a valve chamber 15 between a closed and an inoperative position; in an intermediate position fuel flows through at least one throttle 24. A spring 13 biases the actuator to the inoperative position. The actuator has a closing head 23 with a pressure surface which, in the inoperative position, is acted upon by fuel pressure on the pump side over a partial surface 26 which is smaller than the total surface acted upon in the closed or intermediate positions in a ratio such that, on starting, the actuator 14 is opened from the inoperative position only when a pressure is applied to the partial surface to move the actuator against the spring force. Thus the pressure needed to move the shut-off valve 8 out of the inoperative position is appreciably higher than that needed to move it out of the intermediate position.

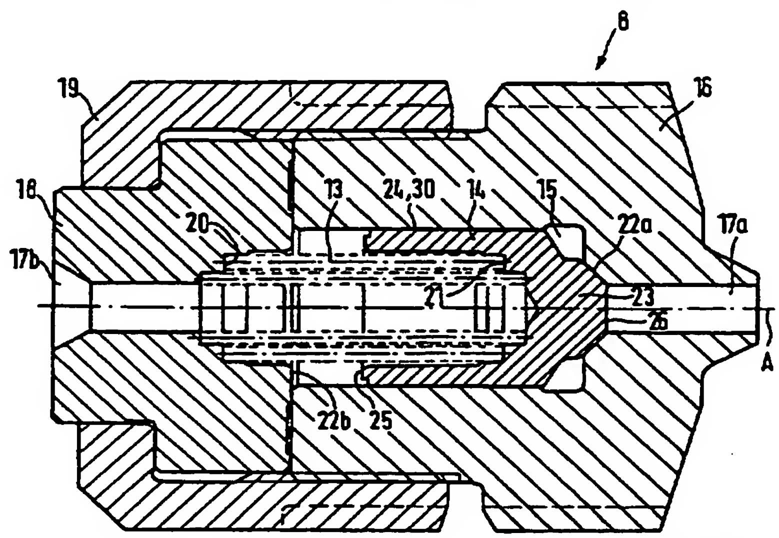

FIG.2a

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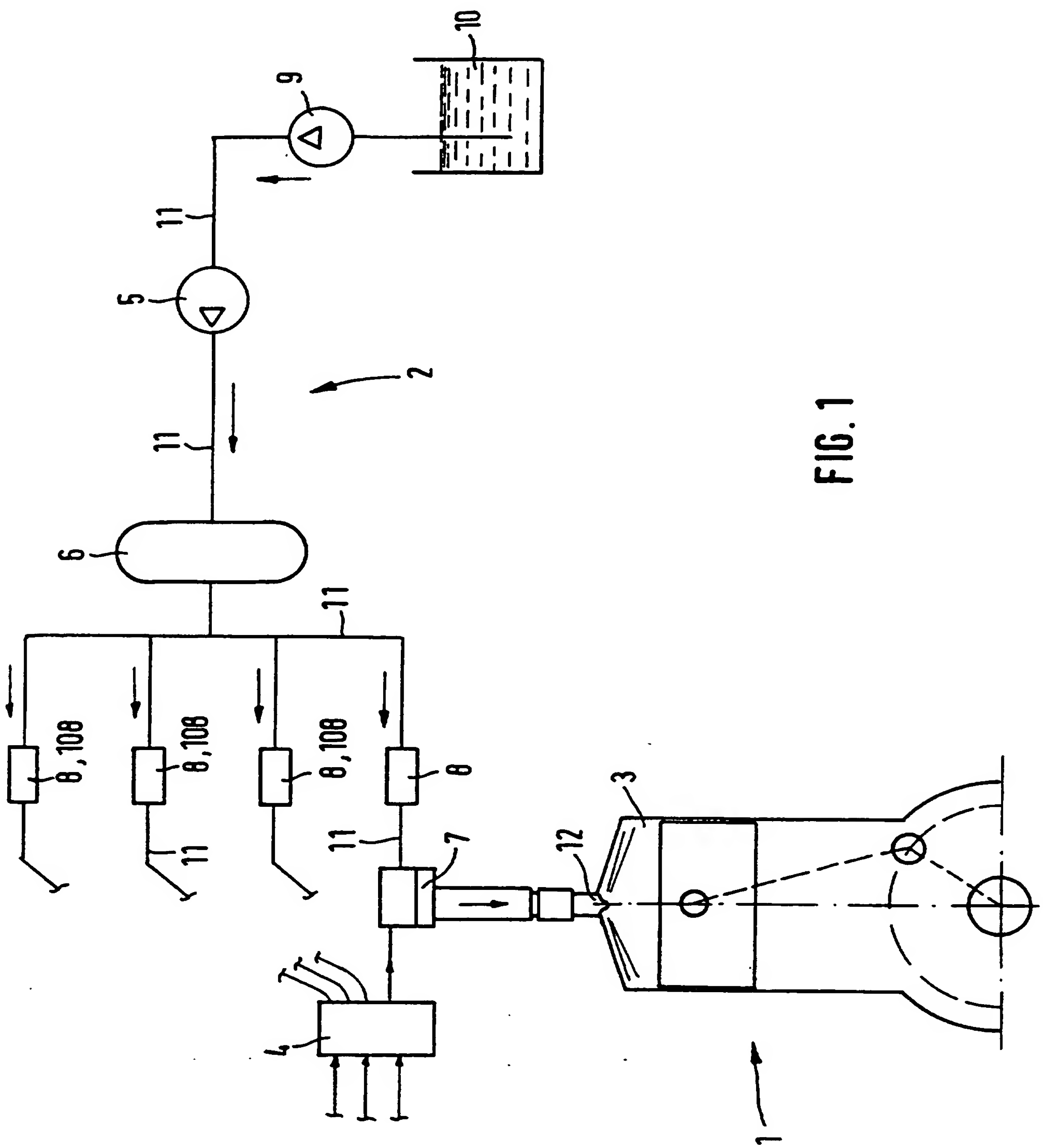

FIG. 1

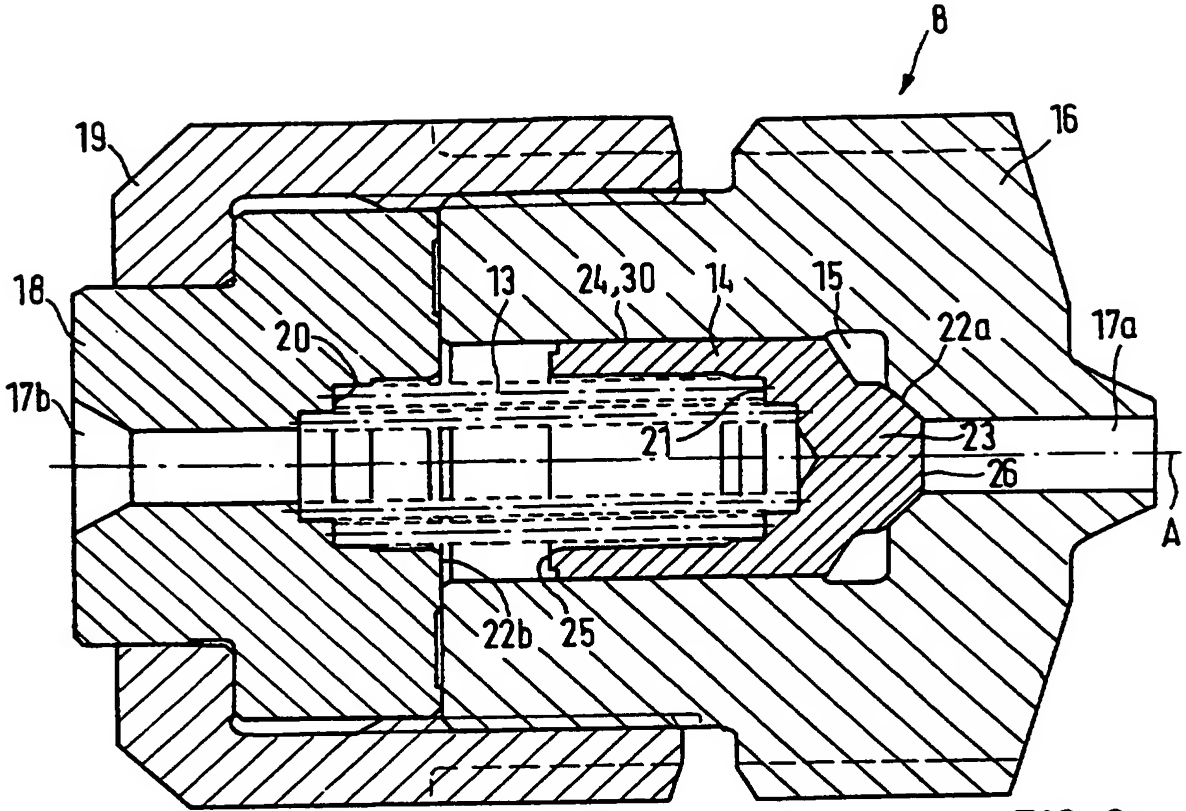
8
19
16
18
13
24,30
14
15
20
22a
17a
17b
21
23
26
A
22b
25

FIG.2a

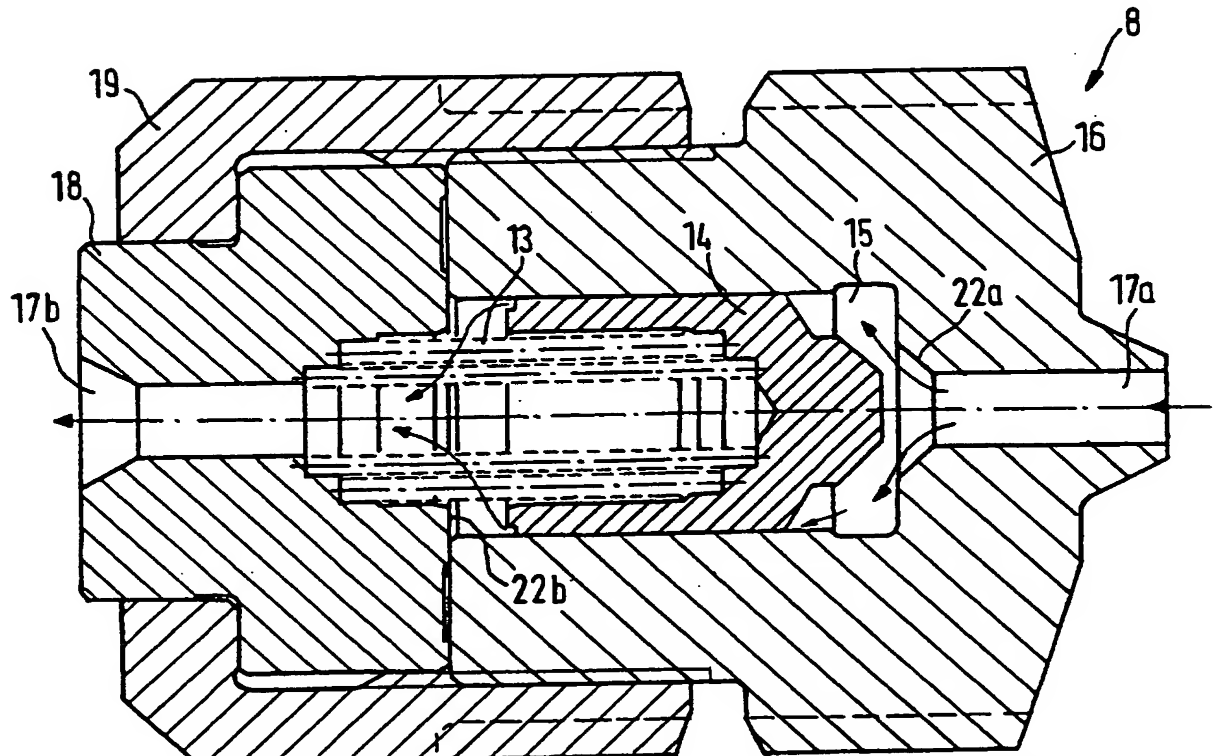
8
19
16
18
13
14
15
22a
17a
17b
22b

FIG.2b

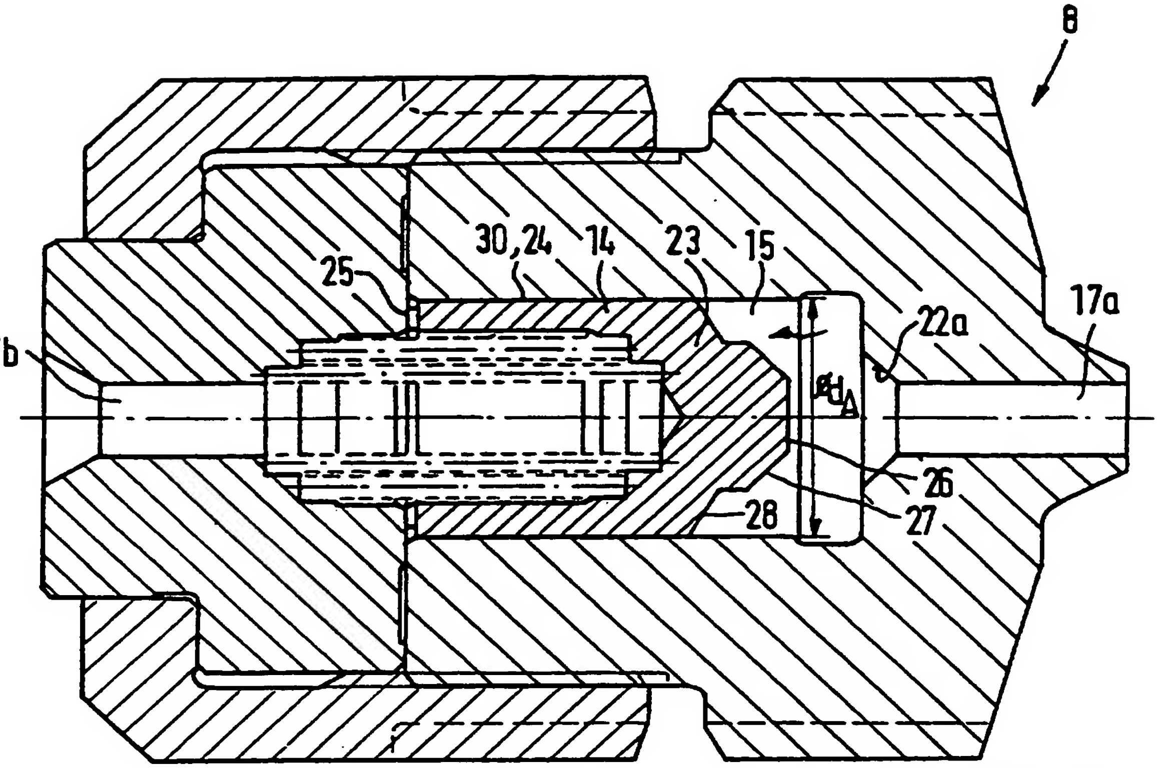
8
30,24
14
23
15
25
17b
22a
17a
ø d_A
26
27
28

FIG.2c

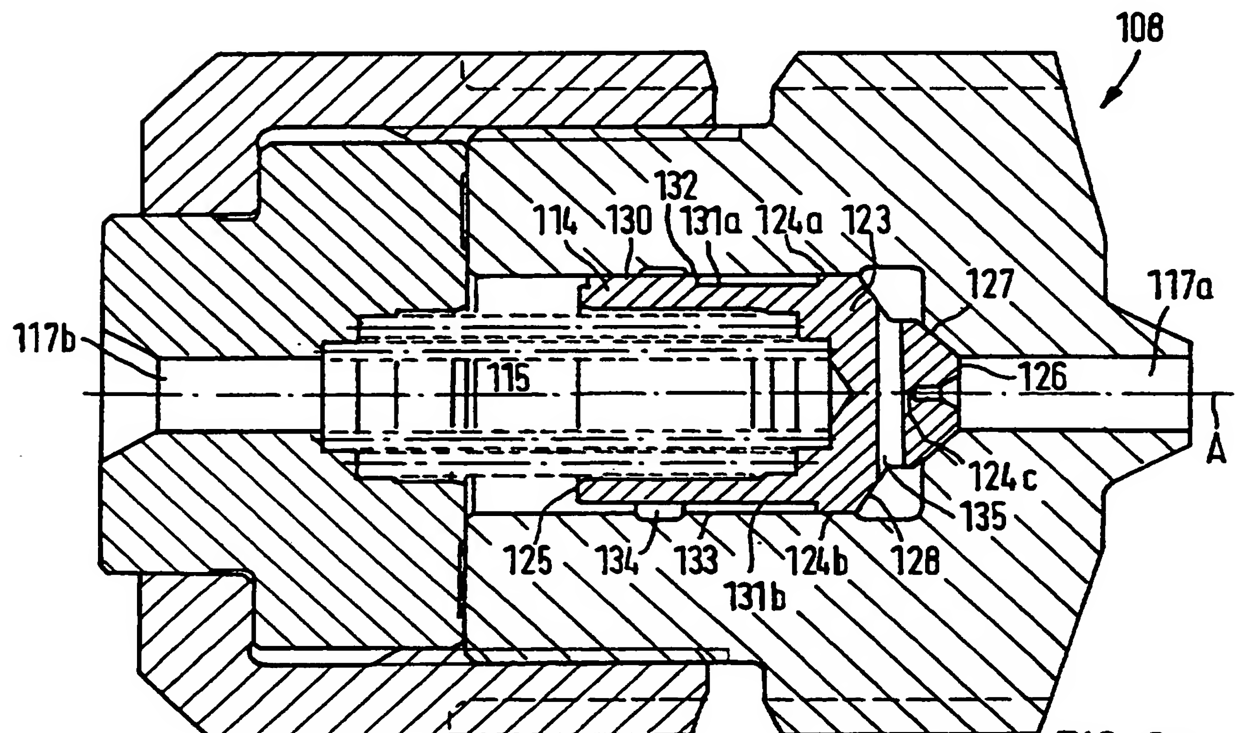
108
132
114
130
131a
124a
123
127
117a
117b
115
126
A
124c
135
125
134
133
124b
128
131b

FIG.3a

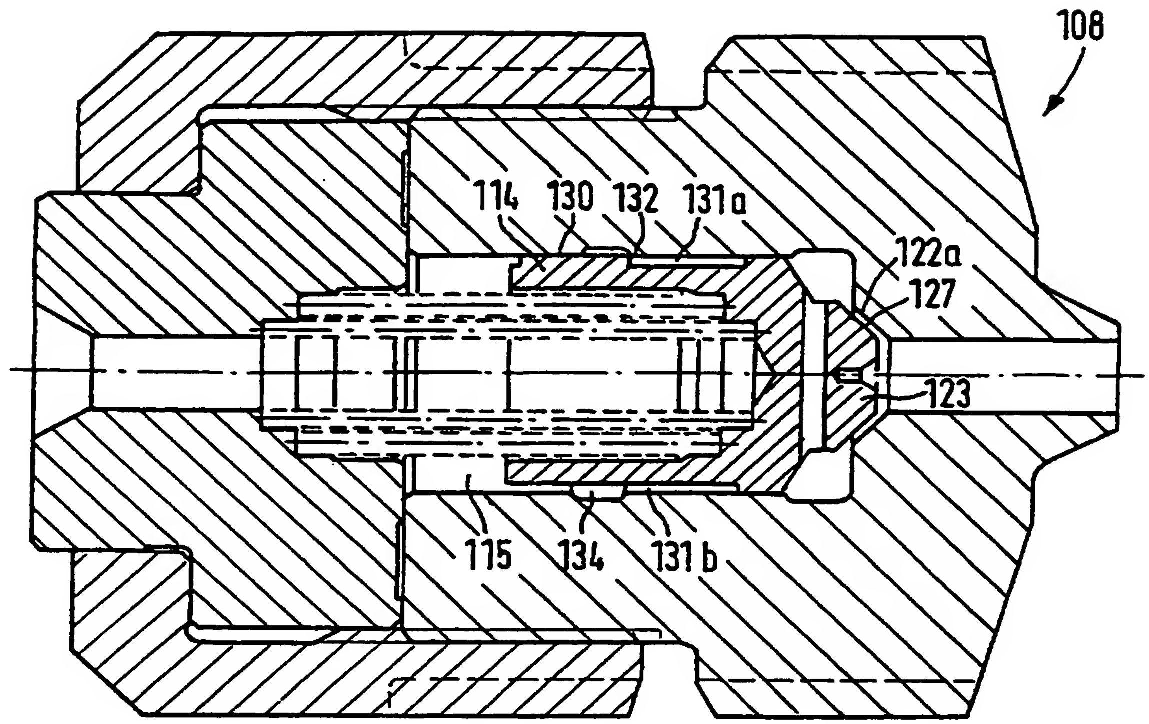
108
114
130
132
131a
122a
127
123
115
134
131 b

FIG.3b

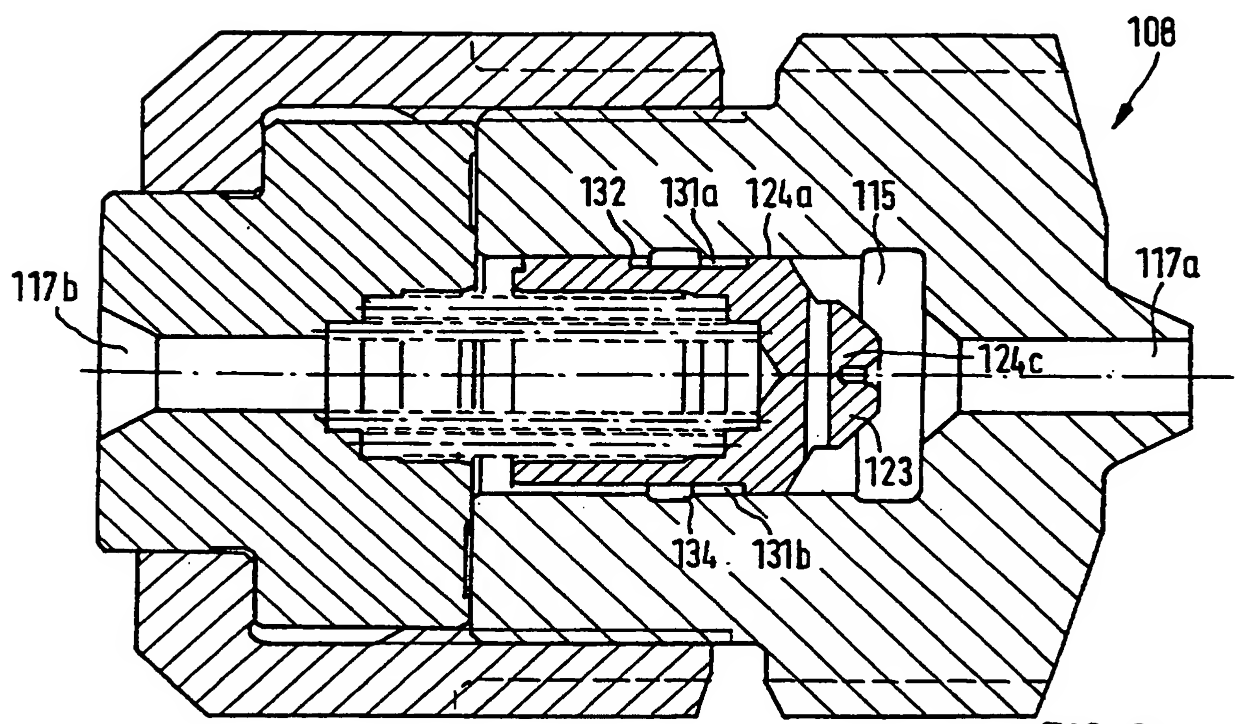
108
132
131a
124a
115
117b
117a
124c
123
134
131b

FIG.3c

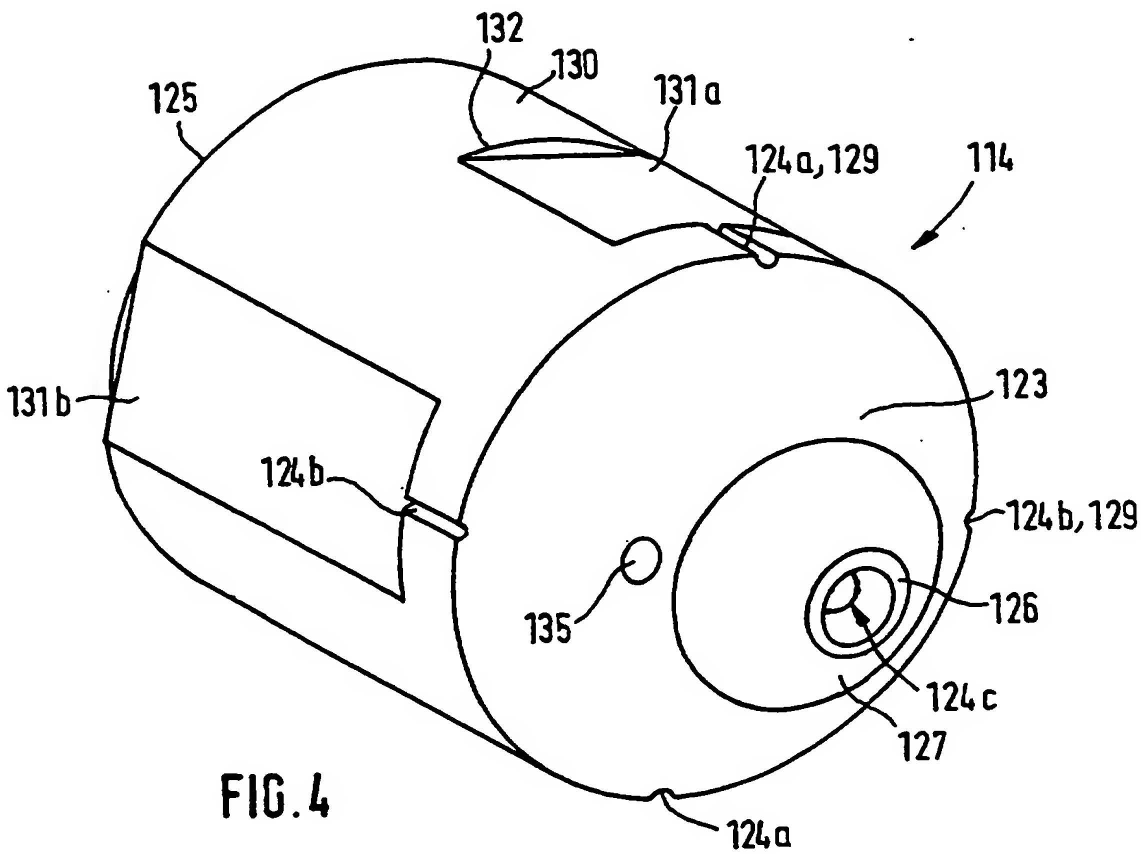
132
130
125
131a
124a,129
114
123
131b
124b
124b,129
135
126
124c
127
124a

FIG.4

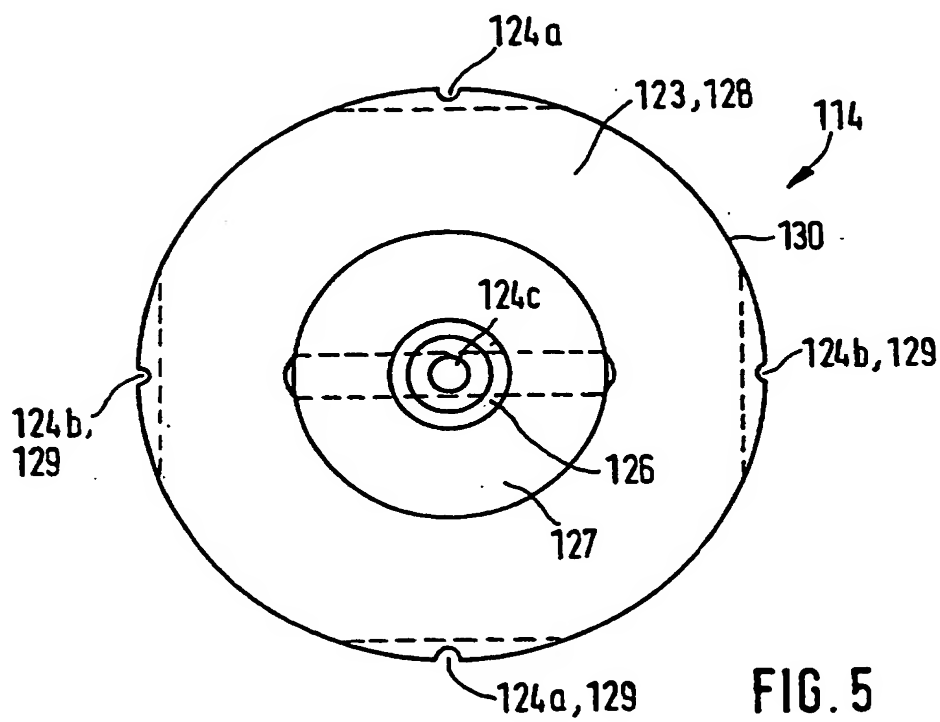
124a
123,128
114
130
124c
124b,129
124b,
129
126
127
124a,129

FIG.5

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M&C Folio: 230P77802

A Shut-off Valve for Limiting Flow Volume

The present invention relates to a shut-off valve for limiting the flow volume for an internal combustion engine comprising a fuel injection system according to the preamble of claim 1. A shut-off valve of this kind is disclosed in German Offenlegungsschrift 43 44 190.

A substantial reason for developing fuel injection systems with high-pressure fuel accumulators, so-called accumulator injection systems, is that the injection characteristics can be very variably controlled because specially adapted, electromagnetically controllable injection valves can be used, because of their flexibility, to suit the particular engine operating requirements. In contrast, in conventional fuel injection systems driven by a camshaft the injection characteristics are influenced by the cam lift, which means that the injection timing and injection period may be varied only to a limited extent. Electronically controlled accumulator injection systems thus permit fuel-efficient and low-emission operation of diesel engines.

In an accumulator injection system such as the one disclosed in the aforementioned Offenlegungsschrift, a high-pressure fuel accumulator is filled up by a high-pressure pump with fuel to a desired pressure level. The injection valves on the cylinder side are connected via feed pipes to the high-pressure accumulator. If injection is to occur at a

particular piston position of the internal combustion engine, then the flow from the fuel accumulator to the injection nozzles of the injection valve on the cylinder side is freed via the injection valves and is shut off again when the injection operation is required to end. This procedure is controlled by means of an electronic control unit which is operated by state variables of the internal combustion engine, among other things.

If, for example, one of the injection valves fails, there is the risk that the injection nozzles will continue to inject fuel into the cylinder chamber of the engine. This could result in the particular engine cylinder being damaged. Also, the high-pressure fuel accumulator is unloaded in such a way that the functional performance of the other injection valves connected to the fuel accumulator may be disrupted, thereby affecting the performance of the other engine cylinders as well. To solve this problem, the Offenlegungsschrift proposes a shut-off valve installed upstream of the injection valves to limit the flow volume, the said shut-off valve having a piston which is movable longitudinally in a valve chamber between a closed and an open position and which, under the effect of the feed pressure, essentially expels the quantity of fuel arriving for injection. The considerable advantage of the proposal is that, with a continuing pressure-loss downstream of the shut-off valve, the fuel supply to the defective injection valve is stopped with virtually no delay, so that the leak remains without further consequences with respect to the other injection components. If, however, an injector leaks while the internal combustion engine is being started,

the operation of the shut-off valve is then jeopardized, as the rotational speed of the pump and therefore the quantity of fuel delivered is so low on starting that it flows through the return throttles of the actuator without having a pressure difference that would be sufficient to push the actuator against the force of the return spring into the closed position. This malfunction could cause the delivered fuel to flow into the combustion chambers of the engine without the engine being able to start, as the injection pressure remains too low.

Proceeding from the above, an object of the present invention is to provide a shut-off valve of the type previously defined which ensures that the internal combustion engine will start even with incorrectly open injection valves.

The invention provides a shut-off valve as claimed in claim 1.

The invention has the advantage that, because of the said surface ratio, when the engine is started, the actuator is opened from the inoperative position only when a pressure is applied to the partial surface to move the actuator against the force of the spring. As a result, the pressure necessary to move the shut-off valve out of the inoperative position is appreciably higher than the pressure necessary to move the actuator out of an intermediate position. When the engine is started, therefore, no fuel will flow initially to the injection valves until the force resulting from the fuel pressure on the intake side exceeds the closing force of the

shut-off valve. The pressure is now high enough to move the actuator into the closed position in the event of a defect. The flow of fuel can thus be reliably discontinued even while starting the internal combustion engine without interfering with the starting operation of the other cylinders.

Preferred embodiments of the invention are explained below with reference to the accompanying drawings, in which:

Fig. 1 shows diagrammatically a fuel injection system for an internal combustion engine in the accumulator injection system version,

Fig. 2a shows a longitudinal section of a shut-off valve with the actuator in the inoperative position,

Fig. 2b shows a longitudinal section of the shut-off valve according to Fig. 2a with the actuator in the intermediate position,

Fig. 2c shows a longitudinal section of the shut-off valve according to Fig. 2a with the actuator in the closed position,

Fig. 3a shows a longitudinal section of an alternative version of the shut-off valve with the actuator in the inoperative position,

Fig. 3b shows a longitudinal section of the shut-off valve according to Fig. 3a with the actuator in an

intermediate position close to the inoperative position,

Fig. 3c shows a longitudinal section of the shut-off valve according to Fig. 3a with the actuator in an intermediate position with the groove/control edge arrangement open,

Fig. 4 shows a perspective view of the actuator according to Fig. 3a, and

Fig. 5 shows a head-end view of the actuator according to Fig. 3a.

As shown diagrammatically in Fig. 1, fuel is supplied to an internal combustion engine 1 in the form of a diesel engine via a fuel injection system 2 for a cylinder 3 of the engine 1. In a diesel engine fuel is injected intermittently, separately for each cylinder 3, the timings for starting and ending injection and also the injection volume at a given injection pressure being controlled by an electronic control unit 4. To enable it to do this, operating variables of the engine and the actual accelerator position are supplied to the control unit 4.

The fuel injection system 2 comprises a high-pressure fuel injection pump 5 for continuously filling a fuel accumulator 6 and an injection valve 7 and a shut-off valve 8 for each cylinder. For the sake of simplicity, only the injection valve 7 for one cylinder 3 is shown as an example.

During operation, fuel is delivered continuously by a low-pressure fuel pump 9 from the fuel tank 10 and supplied to the fuel accumulator 6. The high-pressure fuel pump 5 located between the low-pressure fuel pump 9 and the high-pressure fuel accumulator 6 and operated by the internal combustion engine 1 ensures the required pressure level in the fuel accumulator 6. Depending on the design of the fuel injection system 2, the pressure in the fuel accumulator 6 is 1000 bar and above. The volume of the fuel accumulator 6 is a multiple of the fuel injection quantity for each injection period, namely about a hundred times this amount. The fuel which is under high pressure is supplied by further feed pipes 11 to the injection valves 7 where, after the opening of the injection valves 7, it is then injected via the injection nozzles 12 of the injection valves 7 on the cylinder side for combustion with the compressed air present in the cylinders 3.

If a defect like a leak downstream of the shut-off valve 8, such as an incorrectly open injection valve 7 for example, appears during operation, fuel would then flow continuously from the fuel accumulator 6 into the cylinder 3, with the result that the fuel accumulator 6 would very soon be emptied and would jeopardize the operation of the fuel injection system 2 in the delivery of fuel to the remaining cylinders 3 which are still functioning. So that the failure can be limited to one cylinder 3, a shut-off valve 8 is connected between each of the injection valves 7 and the fuel accumulator 6 to limit the flow volume. The effect of the shut-off valves 8 is that only a specific amount of fuel can

flow to the injection valves 7 during an injection period. An injection period is characterised by a drop in pressure which occurs downstream of the shut-off valve 8 either during the injection process or in the event of a leak.

Fig. 2a, 2b and 2c show the design of a shut-off valve 8 with a cup-shaped actuator 14 loaded by a compression spring 13. The actuator which is displaceable longitudinally in the cylindrical valve chamber 15 of the shut-off valve 8 between a closed and an inoperative position is shown in Fig. 2a in its inoperative position.

The valve chamber 15 is shaped like a blind hole in a cup-shaped valve housing 16, the valve chamber 15 having at one of its ends a connection 17a on the pump or intake side for connection to the feed pipe 11. At its opposite end the valve chamber 15 is bounded by a housing cover 18 which is fastened to the valve housing 16 by means of a union nut 19. Adjacent the valve chamber 15, the housing cover 18 has a spring seat 20 in the form of a stepped bore to accommodate the compression spring 13. The helical compression spring 13 which extends in the axial direction is thus seated on the spring seat 20 at one end and its other end presses against the base 21 of the actuator 14. The cup-shaped actuator extends with its open side towards the housing cover 18 and inverts the compression spring 13 a little way. The housing cover 18 also has a connection 17b which opens into the valve chamber 15 and connects it to the feed pipe 11 on the injection valve or discharge side.

So that the actuator 14 has a defined closed and inoperative position, the valve chamber 15 through which fuel flows in the longitudinal direction of the chamber has valve seats 22a and 22b respectively at its intake and discharge ends, the one formed in the valve housing 16 and the other in the housing cover 18.

As the inoperative position shown in Fig. 2a reveals, the closing head 23 of the actuator 14 formed on the intake side thereof is seated on the conical valve seat 22a on the intake side, so that the shut-off valve 8 is initially closed and fuel cannot enter the valve chamber 15. If there is now a drop in pressure on the injection side due to the injection process which is beginning or a leak, the piston-like actuator 14 moves against the force of the compression spring 13 towards the valve seat 22b on the discharge side. When, in the case of injection, the required fuel quantity has been injected into the cylinder 3, the injection valve 7 closes the fuel passage to the cylinder 3, with the result that the actuator 14 stops in an intermediate position between the closed and the inoperative position, as shown in Fig. 2b, and as a result of the fuel pressure downstream of the actuator 14 which is rising again and under the effect of the force of the compression spring 13 the actuator 14 is finally moved back again towards the inoperative position.

As a result of a first throttle 24, which, in the embodiment shown in Fig. 2a to 2c, is a radial clearance between the piston-like actuator 14 and the cylindrical valve chamber 15, a connection remains between the two ends of the

valve chamber 15 as the actuator slides back, so that fuel can subsequently flow along the circumferential surface 25 of the actuator 14 on the discharge side into the valve chamber 15. The actuation speed of the actuator 14 can be influenced by the dimensions of the first throttle 24.

If the pressure drop as a result of a leak on the injection side continues and fuel beyond the maximum injection quantity is discharged, the sealing surface of the actuator 14 formed on the peripheral margin 25 thereof moves into abutment against the valve seat 22b on the cover side, as shown in Fig. 2c. The actuator 14 thus stops a subsequent flow of fuel by its inability to make a further expelling movement when in its closed position, on the one hand, and on the other hand by the close abutment of the whole peripheral margin 25 against the valve seat 22b, causing the connection to be discontinued, with the result that the subsequent flow of fuel through the first throttle 24 is no longer possible.

To ensure that the shut-off valve is also able to function when the internal combustion engine 1 is being started, the actuator 14 has a closing head 23 with stepped cross-sections. For this purpose the closing head 23 has an end face 26 on the intake side extending perpendicularly to the valve axis, which is smaller than the total surface on which pressure is able to act in the intermediate position. This total surface results from the external diameter d_A of the actuator 14. This stepped shape of the actuator 14 enables the situation to be avoided in which a relatively low fuel pressure during starting is sufficient to move the actuator 14

into an intermediate position from which, in the event of a defect, it is nevertheless impossible to reach the closed position due to the low fuel pressure. Under such conditions the actuator 14 would remain in an intermediate position, and fuel would pass the shut-off valve 8 unhindered via the throttle 24. To avoid this, during the starting process the actuator 14 which is in the inoperative position is acted upon by fuel pressure over only a partial surface, i.e. the end face 26. The size ratio of this partial surface to the total surface and the spring characteristic of the compression spring 13 are dimensioned such that the actuator 14 only opens at a fuel pressure which, if a leak is present, can move the actuator 14 into its closed position. If the sealing surface 27 created adjacent the end face 26 lifts off the valve seat 22 on the intake side, pressure acts on the effective pressure surface of the shut-off valve 14, comprising the end face 26, the sealing surface 27 and a residual surface 28 which widens in a cone shape into the external diameter. The total surface which is now entirely acted upon by pressure produces an increased pressure which is able to overcome the spring force directed in the opposite direction.

A second embodiment is shown in Fig. 3a to 3c and in Fig. 4 and 5. In the shut-off valve 108 illustrated in these figures, the first throttle 124 which creates the fuel-conveying connection between the two ends of the valve chamber 115 when the actuator 114 is in the intermediate position is, as Fig. 4 and 5 show, a groove 129 extending in the axial direction in the circumferential surface 130 of the actuator 114. This first throttle 124, of which there is another one

diametrically opposite on the circumferential surface 130, opens on the discharge side into a first recess 131 which in cross-section is in the shape of a segment and ends with a control edge 132 spaced from the peripheral margin 125. Provided on the circumferential surface 130 spaced in the peripheral direction from the first throttles 124 is a pair of second throttles 133 which create a second fuel-conveying connection between the two ends of the valve chamber 115. These second throttles 133 also open on the discharge side into a second recess 131b in the shape of a segment which extends in the axial direction and opens at the peripheral margin 125 on the discharge side into the valve chamber 115.

As is evident in Fig. 3a to 3c, a peripheral groove 134 is machined into the valve chamber wall 133, which, depending on the position of the actuator 114, connects the first recesses 133a to the second recesses 131b so that they convey fuel. The control edge 132 and the peripheral groove 134 are positioned axially in such a way that, when the actuator 114 is in the inoperative position, the fuel-conveying connection between the two ends of the valve chambers 115 is shut off by fuel being prevented from flowing from the first recess 131a via the peripheral groove 134 into the second recess 131b.

The actuator 114 is shown in Fig. 3b in an intermediate position in which it is located just before or just after the inoperative position. In this intermediate position the control edge 132 covers the margin of the peripheral groove 134 on the intake side, so that, with further movement towards the closed position, the connection between the two recesses

131a and 131b is opened, as shown in Fig. 3c. As the actuator 114 returns from an intermediate position towards the inoperative position, as is evident in Fig. 3c, the return speed of the actuator 114 slows down as soon as the groove/control edge arrangement 129, 132 shuts off the fuel-conveying connection via the first throttle 124a, since the speed of flow of the fuel from one end to the other end of the valve chamber 115 decreases. The throttle cross-sections of the first and second throttles 124a and 124b respectively are adapted to one another so that, in normal operation, the inoperative position is not reached but the actuator 114 moves to and fro between an intermediate position on the intake and the discharge side. This prevents pressure surges, originating from the opening operation when the actuator is freed from the inoperative position, from adversely affecting the injection behaviour.

Another feature ensuring the functional performance of the shut-off valve 108 is evident in the design of a third throttle 124c in the closing head 123. This third throttle 124c, which opens in the end face 126, is a throttle bore which opens on the discharge side in a bore 135 which extends transversely. The two ends of this bore 135 in turn open into the valve chamber 115 downstream of the sealing surface 127, so that when the actuator 114 is in the inoperative position as shown in Fig. 3a, there is a connection between the connection 117a on the intake side and the valve chamber 115 via the third throttle 124c. The third throttle 124c enables the fuel-conveying parts downstream of the shut-off valve 108 to be vented while starting the internal combustion engine 1.

Fuel is still able to flow while the actuator 114 is in the inoperative position via the second and third throttle 124b and 124c respectively to the [connection][1] 117b on the discharge side, with the result that any air which might be present there can be expelled by the fuel flowing in subsequently, without the actuator 114 dropping into its closed position due to the compressibility of the air during the starting process, thereby unintentionally preventing the engine 1 from being started.

Claims:

1. A shut-off valve for an internal combustion engine with a fuel injection system, the shut-off valve being arranged in a feed pipe between a fuel injection pump and a fuel injection valve and having a cylindrical valve chamber connected at opposite ends thereof to the feed pipe and in which an actuator:

a) is axially movable in the valve chamber between a closed position on the injection side and an inoperative position on the pump side,

b) has at least a first throttle via which a fuel-conveying connection is made between the two ends of the valve chamber when the actuator is in an intermediate position,

c) is loaded by a spring acting in the inoperative position,

d) has at the intake end a closing head with a pressure surface which, in the inoperative position, is acted upon by fuel pressure on the pump side over a partial surface smaller than the total surface acted upon in the closed or intermediate position,

characterised in that the surface ratio of the said partial surface to the said total surface is such that, when the engine is started, the actuator is opened from the inoperative

position when a pressure is applied to the partial surface to move the actuator against the spring force.

2. A shut-off valve according to claim 1, wherein the actuator has at least a second throttle creating a second fuel-conveying connection between the two ends of the valve chamber when the actuator is in an intermediate position, the connection being shut off via the first throttle shortly before the actuator reaches the inoperative position.

3. A shut-off valve according to claim 2, wherein the first connection is opened and shut off via a cooperating groove/control edge arrangement created in the contact region between the actuator and the valve chamber wall.

4. A shut-off valve according to claim 1 or 2, wherein the first and second connection is formed by a first and a second recess which are connected to the first and second throttle, respectively, which recesses extend axially on the circumferential surface of the actuator, the second recess opening on the discharge side into the valve chamber, and a peripheral groove communicating with the first and second recess being machined into the wall of the valve chamber, which peripheral groove is connected via the first recess to the first throttle when the actuator is in the intermediate position and up to shortly before it reaches the inoperative position.

5. A shut-off valve according to any one of the preceding claims, wherein the first and/or second throttle is formed by

a throttle gap extending between the valve chamber wall and the actuator.

6. A shut-off valve according to any one of the preceding claims, wherein the first and/or second throttle is a throttle groove extending on the wall of the cylindrical valve chamber and/or on the circumferential surface of the actuator.

7. A shut-off valve according to any one of the preceding claims, wherein the first and/or second recess forms a segment-shaped section.

8. A shut-off valve according to any one of the preceding claims, wherein the actuator has two axially-spaced guide rings surrounding the periphery thereof, and guiding the actuator closely adjacent the cylindrical wall of the valve chamber, the rings having breaks serving as the first and/or second throttle.

9. A shut-off valve according to any one of the preceding claims, wherein the pressure surface of the closing head has an end face forming the partial surface, a residual surface and a valve seat sealing surface located therebetween, which form the total surface on which pressure may act.

10. A shut-off valve according to claim 9, wherein the closing head has a further throttle which, when the actuator is in the inoperative position, creates a fuel-conveying connection on either side of the sealing surface.

11. A shut-off valve according to claim 10, wherein the throttle cross-section of the further throttle is such that, during malfunction-free operation of the fuel-injection system, the downstream feed pipe is vented or filled while the engine is being started.

12. A shut-off valve according to claim 10 or 11, wherein the residual surface and/or the sealing surface are a tapering portion of the closing head.

13. A shut-off valve according to any one of the preceding claims, wherein the shut-off valve has, as well as the first throttle, the second and the further, third throttle, the flow volumes q thereof being $q_1 > q_2 > q_3$.

14. A shut-off valve substantially as herein described with reference to either of the embodiments shown in the accompanying drawings.

15. A fuel injection system having a shut-off valve as claimed in any one of the preceding claims.

Patent Office

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Application No:	GB 9720570.2	**Examiner:**	John Twin
Claims searched:	1 to 15	**Date of search:**	30 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B (B2JB); F2V (VA22, VV3)

Int Cl (Ed.6): F02M 59/46, 63/02; F16K 17/30

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2305468 A	(Robert Bosch)	
A	WO 96/26362 A1	(Robert Bosch)	
A	WO 95/17594 A1	(L'Orange)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		